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Space Acceleration Measurement System Description and Operations on the First Spacelab Life Sciences Mission

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SPACE ACCELERATION MEASUREMENT SYSTEM DESCRIPTION AND OPERATIONS ON THE FIRST SPACELAB LIFE SCIENCES MISSION

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SUMMARY

The mission of NASA's microgravity science program is to utilize the unique characteristics of the space environment, primarily the near absence of gravity, to expand man's knowledge of physics, chemistry, materials and fluid sciences, and biotechnology; to understand the role of gravity in materials processing; and, where possible, to demonstrate the feasibility of space production of improved materials that have high technological, and possible commercial, utility. [1]

Environmental factors (e.g., temperature, pressure, acceleration level) are typically measured during the science missions to characterize the conditions to which the experiments were exposed. Many science experiments which are particularly sensitive to acceleration levels incorporated an accelerometer into the experiment package design. The need for a general purpose acceleration measurement system originated from these numerous special purpose accelerometers. A general purpose system could be utilized as a standard to measure the microgravity environment for many diverse experiments in different locations on the Orbiter. Such a general purpose system would also be capable of reflights and reconfiguration for the support of different experiments on successive missions. The Space Acceleration Measurement System (SAMS) project was formed to develop such a general purpose acceleration measurement instrument.

Measuring the acceleration environment during an experiment's operation allows the experimental data to be analyzed considering the affects of the localized acceleration environment on the experiment's operation and/or data.

The SAMS development process has resulted in flight units for the Orbiter middeck, Spacelab module and Orbiter cargo bay. The first SAMS unit to fly has successfully operated and acquired data on the first Space Life Sciences mission, STS-40, in June 1991. Shuttle mission STS-40, the 41st flight of the Space Shuttle and the 11th flight of Columbia, conducted the Spacelab Life Sciences (SLS-1) mission which was the first spacelab mission dedicated to life sciences research.

Acceleration data was acquired for 7 days, 0 hours, and 3 minutes which corresponds to 371 Mbytes of data. The data is continuous except for two periods when the SAMS unit was turned off (approximately thirty seven minutes).

This report presents a description of the SAMS flight units and the preparation of the first flight unit for the SLS-1 mission. The subsequent operation during the mission is discussed and a brief look at the acquired data is presented.

ACRONYMS

ACAP	Acceleration Characterization and Analysis Project
BRS	Body Restraint System
EDT	Eastern Daylight Time
FES	Fluid Experiment System
g	Normal Gravity Level at Earth's Surface
GMT	Greenwich Mean Time
JSC	NASA Johnson Space Center
KSC	NASA Kennedy Space Center
LeRC	NASA Lewis Research Center
MET	Mission Elapsed Time
MSAD	Microgravity Science And Applications Division
OARE	Orbital Acceleration Research Experiment
RDE	Rotating Dome Experiment
SAMS	Space Acceleration Measurement System
SET	SAMS Elapsed Time
SLS	Spacelab Life Sciences
SMIDEX	Spacelab Middeck Experiments
SSCE	Solid Surface Combustion Experiment
STS	Space Transportation System
TSH	Triaxial Sensor Head
UTWG	Utilization Technology Working Group

INTRODUCTION

The mission of NASA's microgravity science program is to utilize the unique characteristics of the space environment, primarily the near absence of gravity, to expand man's knowledge of physics, chemistry, materials and fluid sciences, and biotechnology; to understand the role of gravity in materials processing; and, where possible, to demonstrate the feasibility of space production of improved materials that have high technological, and possible commercial, utility. [1]

Environmental factors (e.g., temperature, pressure, acceleration level) are typically measured during the science missions to characterize the conditions to which the experiments were exposed. Many science experiments which are particularly sensitive to acceleration levels incorporated an accelerometer into the experiment package design. The need for a general purpose acceleration measurement system originated from these numerous special purpose accelerometers. A general purpose system could be utilized as a standard to measure the microgravity environment for many diverse experiments in different locations on the Orbiter. Such a general purpose system would also be capable of reflights and reconfiguration for the support of different experiments on successive missions.

The SAMS project was conceived in 1986 in order to develop such a general purpose instrument to measure low-levels of acceleration at experiment locations on the space shuttle Orbiter. SAMS has been developed by the NASA Lewis Research Center (LeRC) for the NASA Headquarters Office of Space Science Applications, Microgravity Science and Applications Division (MSAD). The primary experiments to be supported are those funded by the MSAD, although other experiments are supported through arrangements with MSAD.

Acceleration disturbances on earth are composed of a constant component (earth's gravity, referred to as 1 g) and oscillatory accelerations, such as, earth tremors, mechanical systems (e.g., air conditioners, fans), etc. Acceleration disturbances are vector quantities and can be characterized by their magnitude, direction, duration and frequency content.

Acceleration disturbances affect different processes in different ways. For example, in fluid flow experiments, the direction and speed of the fluid flow may be affected by low frequency accelerations. In contrast, fundamental physics experiments may be affected by energy input from accelerations over a broad-band of frequencies. These acceleration disturbances may be reduced by subjecting the experiment to a low residual acceleration environment on-board the Orbiter, although other time dependent sources unique to a spacecraft vehicle (such as firing of thrusters) may be introduced at the same time.

Measuring the acceleration environment during an experiment's operation

allows the experimental data to be analyzed considering the affects of the localized acceleration environment on the experiment's operation and/or data.

The need for a general purpose acceleration measurement system originated from the numerous special purpose accelerometers fabricated as part of science experiments. Conceptually, such a general purpose system could be utilized to measure the microgravity environment for many diverse experiments in different locations on the Orbiter. This general purpose system would also be capable of reflights and reconfiguration for the support of different experiments.

The development process has resulted in SAMS flight units for the Orbiter middeck, Spacelab module and Orbiter cargo bay. The first SAMS unit to fly has successfully operated and acquired data on the first Space Life Sciences mission, STS-40, in June 1991. This report presents a description of the SAMS flight units and the preparation of the first flight unit for the SLS-1 mission. The subsequent operation during the mission is discussed and a brief look at the acquired data is presented.

SAMS FLIGHT UNITS

Unit Description

Each SAMS flight unit is comprised of a main unit, up to three remote triaxial sensor heads (TSH's), and sensor head cables to connect the sensor heads to the main unit (figure 1). Each TSH contains three acceleration sensors in an orthogonal orientation to measure the acceleration vector's three orthogonal components (figure 2). Each acceleration sensor also contains an integral temperature sensor. The SAMS main unit samples the acceleration, temperature, time, and peripheral data and stores this data on optical disks. For the SAMS units in the middeck and Spacelab module, the optical disk drives allow the crew members to change disks during a mission allowing for essentially an unlimited amount of data storage. The SAMS unit in the Orbiter cargo bay is installed in sealed containers, and therefore the disks are inaccessible to the crew.

Mechanically, the SAMS main unit was designed for installation in the Orbiter middeck replacing a locker. This design also allows installation in a Spacelab middeck experiments (SMIDEX) rack in the Spacelab module and in the Spacelab module center aisle.

The science experiments which will be supported by SAMS will have different acceleration measurement requirements. The TSH's and the main unit are designed for sampling accelerations with a low-pass filter. Each of the three TSH's may be independently configured with one of six low-pass filter cutoff frequencies of 2.5, 5, 10, 25, 50 and 100 Hertz. The main unit samples the data from the TSH at a

sampling rate equal to five times the low-pass filter cutoff frequency, i.e., 12.5, 25, 50, 125, 250 and 500 samples per second, respectively.

Each acceleration axis in the TSH also contains a programmable, multi-gain amplifier. The gain of this amplifier is controlled by the microprocessor within the main unit according to the level of the acceleration signal relative to the full scale range at the current gain setting. The gain change algorithm keeps the signals from the TSH to be between 5% and 95% of full scale range. The possible gains are 1, 10, 100 and 1000 with full scale ranges of 0.5 g, 0.05 g, 0.005 g and 0.0005 g, respectively. At a gain of 1000, the scale factor is approximately 10,000 volts per 1 g.

During on-orbit operation, each axis in the TSH may be tested for noise level and/or bias of the SAMS electronics. This electronic zero calibration operation is accomplished by electronically disconnecting the acceleration sensor from the amplifier in the TSH and shorting the input of that amplifier. This information may be used during post-mission data compensation for offset adjustment.

The SAMS unit has an internal real-time clock. The time from this clock is recorded with the acceleration data for post-mission data correlation. This clock has the capability of external synchronization with the Orbiter time, either Mission Elapsed Time (MET) or Greenwich Mean Time. This clock will also maintain correct time in case of loss of synchronization signal and/or loss of power from the Orbiter.

The SAMS project currently has four flight units fabricated for the middeck and Spacelab module installation locations. There will be two flight units fabricated in 1991 for the Orbiter cargo bay location. These six flight units will be assigned to the various microgravity science missions supported by SAMS.

Data Compensation

The SAMS mission data is composed of basically four pieces of information; acceleration measurements, time, temperature and electronic-zero calibration. Flight data compensation utilizes calibration data obtained from a characterization procedure of each TSH before and after each flight and from the electronic zero calibration during the flight.

Each of the flight TSH's are characterized prior to integration to an experiment or vehicle for a mission. At least for the early missions, each of the TSH's used for flight will also be characterized after the mission. The use of this characterization data is discussed in a NASA report (in preparation) entitled, "Triaxial Sensor Head Error Budget". In summary, post-mission data reduction compensates for the errors attributed to axis misalignment vs. temperature, bias vs. temperature, and scale factor vs. temperature.

DATA ANALYSIS

The SAMS project will convert the raw data to engineering units and supply this data to principal investigators, the Acceleration Characterization and Analysis Project (ACAP) at NASA Marshall Space Flight Center and the Utilization Technology Working Group (UTWG). The general objectives of ACAP are to develop a description of the acceleration environment of space flight carriers and establish an expert resource which can provide informed recommendations for the management of available microgravity flight resources. Consequential objectives will be an identification and assessment of carrier disturbance mechanisms and an organization of the relation between the disturbance environment and experiment results. A report entitled "Early Summary Report of Mission Acceleration Measurements from STS-40" is in preparation by ACAP. This report contains a preliminary analysis of the SAMS data from SLS-1 as well as a description of the other accelerometers on the STS-40 mission.

The UTWG is a cooperative working group between NASA and the European Space Agency with participation by the National Space Development Agency of Japan and the Canadian Space Agency. The SAMS data will be furnished to the UTWG in order for data dissemination to be accomplished for foreign investigators and U.S. investigators not under MSAD sponsorship.

STS-40, SLS-1 MISSION

Mission Description

Shuttle mission STS-40, the 41st flight of the Space Shuttle and the 11th flight of Columbia, conducted the Spacelab Life Sciences (SLS-1) mission which was the first spacelab mission dedicated to life sciences research. [2]

During the SLS-1 mission, the STS-40 crew performed experiments which explored how the heart, blood vessels, lungs, kidneys and hormone-secreting glands respond to microgravity. The crew also investigated the causes of space sickness and changes in muscles, bones and cells during the microgravity environment of space flight and in the readjustment to gravity upon returning to Earth. The experiments performed on Columbia's crew and on laboratory animals will provide the most detailed and interrelated physiological measurements acquired in the space flight environment since the Skylab program flights in 1973 and 1974.

The mission duration was nine days and concluded with a landing at Edwards Air Force Base, California on June 14. The SAMS optical disks were removed from the Spacelab module at the landing site. Following the STS-40 mission, Columbia

was returned to KSC, where the spacelab module was removed. The SAMS main unit, cables and sensor heads were removed from the module at KSC.

SAMS Science Support Objectives

The primary experiment supported by the SAMS unit on SLS-1 was the Solid Surface Combustion Experiment (SSCE). The SSCE was investigating the dynamics of solid surface combustion during microgravity conditions. This is being accomplished by burning samples of paper in a sealed chamber while measuring temperatures and photographing the combustion process with movie cameras. The SSCE science team selected 5 Hertz as the desired cut-off frequency for the TSH mounted to the SSCE baseplate.

Another science goal was the initial acquisition of data to allow a future characterization of the Orbiter and Spacelab module structure. Disturbances introduced by the body restraint system (BRS) rotating chair and the bicycle ergometer will be utilized as source accelerations. The accelerations near the sources in the center aisle of the Spacelab module were measured as well as the accelerations in the base of a rack and on the SSCE equipment. Many of the future missions for the SAMS units will contribute data to this effort. This characterization study was accommodated by assigning a cut-off frequency of 5 Hertz to the other two TSH's and mounting them as described in section **Location and Characteristics of Unit A TSH's**.

The data from the SLS-1 mission will be the first SAMS acceleration data to be entered into a data base for characterizing the Orbiter acceleration environment. Each of the SAMS units' data from future missions will contribute to this database for statistically characterizing the various locations on the Orbiter where experiments are typically located, i.e., Orbiter middeck, Spacelab racks, Spacelab center aisle, and the Orbiter cargo bay.

Mission Launch And Time Correlation

After several launch attempts, STS-40 lifted off at approximately 9:25 a.m. Eastern Daylight Time (EDT) on June 5, 1991. This corresponded to MET of 0 days, 0 hours and 0 minutes (MET 000:00:00).

The SAMS unit was turned on near the beginning of flight day two. With no time synchronization from the Spacelab, this began the SAMS internal clock and SAMS Elapsed Time (SET) at day one, zero hours, zero minutes, and zero seconds (i.e., SET = 001:00:00:00). From the notes recorded at the Payload Operations Control Center (POCC) and examination of the recorded data, the power was applied at MET = 001:00:01:24. It is convenient, though not planned, that the two times (MET and SET) differed by less than two minutes. This is due entirely to the specific time at which the crew member applied power to the SAMS unit.

SAMS UNIT A INTEGRATION INTO SLS-1 MISSION

Unit A Preparation

The SAMS unit A was fabricated from September through December 1989 by the SAMS project team at LeRC. Verification of this unit was done at LeRC, NASA Goddard Space Flight Center and the White Sands Test Facility.

During performance and operational testing of the SAMS engineering unit and flight unit A, a possible malfunction mode of the automatic gain control algorithm was identified. The exact characteristics of the Spacelab accelerations could not be simulated before the mission to test the possible problem. To avoid the possibility of a TSH being "locked" at a gain of 1000, the gain for two of the TSH's was restricted to 1, 10 or 100, since the acceleration levels on the mission were not expected to be low enough for the 1000 gain to be utilized. The gain of TSH B was fixed at 10 to ensure that data was acquired in case the gain algorithm failed to perform as designed. Acquisition of usable data was felt to be imperative on this mission, since SLS-1 was the initial flight of a SAMS unit.

During operation and verification of later SAMS flight units, a problem with the microprocessor board was discovered. In some initialization situations, the microprocessor would "hang up" which would require recycling of the power to the SAMS unit. This was discovered and corrected in the other SAMS units at a time when unit A was being verified prior to delivery to KSC for turn over. Since this malfunction had not been observed in unit A, it was decided that the corrective measures would not be incorporated into unit A until after the SLS-1 mission. Alternative crew procedures were developed to handle this situation if it developed during the SLS-1 mission.

A time synchronization signal was unavailable to the SAMS unit for SLS-1 so the SAMS internal real-time clock would begin at zero time when power was applied to the SAMS unit. Correlation of the SAMS time and mission time would be performed by noting the time at which power was applied to the SAMS unit.

The zero calibration operation was performed at the initiation of data recording each time the unit was turned on.

The flight and spare TSH's were characterized by Sundstrand Data Control, Inc. under contract in January of 1990. With the mission actually occurring in June 1991, this characterization data is nearly one and a half years old. When the flight TSH's are de-integrated from the Spacelab module (normally within two months of the mission), they will be re-calibrated by Sundstrand. This second characterization data will be compared with the data from January 1990 to investigate the long-term stability of the TSH's characteristics. This post-flight characterization data will be used for the data reduction due to the relatively short time between the mission and the characterization being performed.

Unit A Delivery and Integration

Unit A was delivered to the NASA Kennedy Space Center (KSC) in April 1990 for a planned launch of SLS-1 in August 1990.

The SAMS main unit was mounted in rack 5 of the Spacelab module, figures 3, 4 and 5. Rack 5 was a single SMIDEX rack which is designed to accommodate middeck style payloads in the Spacelab module.

The TSH A was mounted on the SSCE combustion chamber baseplate to measure the accelerations experienced by the combustion sample. The SSCE equipment was located in rack 7, which was a double SMIDEX rack. The TSH B was mounted on an adaptor plate in the base of rack 5 on a connector bracket panel. The TSH C was mounted on an adaptor plate to the base of the BRS frame in the center aisle of the Spacelab module.

The relative orientation of the TSH axes and the Orbiter body axis system is defined in table 1. The axes in the data presented in this report are the SAMS axes. The relationship of this SAMS data to the Orbiter may be accomplished by a vector transformation.

SAMS OPERATIONS DURING SLS-1 MISSION

Table 2 lists the significant events (relative to SAMS) which occurred during the mission. The SAMS unit was turned off for two periods of time to facilitate moving the BRS frame in preparation for the Rotating Dome Experiment (RDE). This power turn-off was required to disconnect the sensor cable from TSH C. During mission day five, the TSH-C cable was disconnected from the sensor head for approximately four hours while the SAMS unit was still recording. This resulted in the loss of data for TSH-C for that period.

A very late change to the crew procedures was nearly a problem for SAMS initial operation due to the absence of time for crew checkout with the new procedure. This modified procedure for the power-on of SAMS did not include an indication that the disk drive indicator light would extinguish when the initialization was complete. The crew interpreted this as abnormal and reported it as such to the POCC. This was corrected by communication with the POCC. It was (fortunately) realized by the SAMS staff in the POCC that the modified procedure was in error in that the procedure did not indicate that the light would extinguish. The SAMS unit was operating properly and was thus left powered on. The corresponding procedures for later missions have been modified to account for this occurrence.

The mission timeline indicated that power to SAMS would be turned off during setup and operation of the rotating dome experiment. This resulted in

additional operations for the SAMS in terms of terminating recording, power off, power on and re-initialization of recording. These actions resulted in loss of approximately thirty seven minutes worth of data while power was off. Corresponding to the three power on initialization sequences, there were three zero calibration operations performed during the SLS-1 mission as listed in table 2.

During nearly the entire mission, SAMS and ACAP personnel at the POCC maintained a log of mission activities. This log consisted of hand written notes and videotape recordings of crew activities. This log will be utilized during the analysis of the acceleration data by SAMS and ACAP.

Based on early examination of a subset of the SAMS data, the possible problem with the gain change algorithm apparently did not occur during the SLS-1 mission. A more detailed examination of the data will reveal if this problem actually did occur during the mission.

The microprocessor "lock up" problem experienced with the SAMS units did not manifest itself during the mission even though the unit was powered up three times during the mission. The corrective measures will still be incorporated into unit A upon its return to LeRC after de-integration from the Spacelab module.

SAMS DATA FOR SLS-1 MISSION

Acceleration data exists for the approximate time intervals listed in table 3. The total time of the recorded data is 7 days, 0 hours, and 3 minutes which corresponds to 371 Mbytes of data.

The plots of data shown herein are the result of preliminary data processing and analysis of the SAMS data for STS-40. As such, several points should be kept in mind while examining the figures and associated description.

a) The time domain plots were prepared after compensating the raw data for temperature effects on the sensor head bias, scale factor and misalignment. The post-mission characterization of the TSH's have not been performed at this time so there may be some errors associated with bias shifts (for example) since the sensor heads were characterized in January 1990.
b) To improve the resolution of the printed spectrum data displays, a calculated mean value of the time domain data was subtracted when calculating the spectrum plots. If this was not done, in some displays, the mean of the time domain data (at zero Hertz) would "overshadow" the data at higher frequencies.
c) The correlation of this acceleration data and events during the mission are primarily from logbooks maintained during the mission. The mission

timeline data has not been accessed yet for more definitive correlation between acceleration data and mission events and activities.

d) There are several frequency peaks which are present in several of the spectrum plots presented here. The repeated frequencies are approximately 3.6, 4.7, and 5.7 Hertz. These are most likely either structural mode frequencies of the Orbiter and Spacelab equipment and/or other equipment operating in the Spacelab module.

e) The axis system used in these plots is the axes of the particular TSH. In this data, there has been no translation to the Orbiter or Spacelab axis systems.

Plot of Acceleration during Quiet Crew Activity

Figure 6 illustrates the acceleration levels during a quiet time when the crew members were sleeping. Figures 6.a and 6.b represent 5 minutes of data starting at SET = 006:15:25:00 for TSH A, x-axis. This interval includes an event occurring approximately 62 seconds into this interval. This disturbance is shown in detail in figure 6.c for TSH A, y-axis. The corresponding spectrum plot for the y-axis of TSH A (figure 6.d) shows a peak at 3.7 Hertz. This disturbance could be triggered by a vernier thruster firing with a 3.7 Hertz resonance of the Orbiter structure. This resembles Orbiter thruster firing response found during analysis by others using previous Spacelab mission accelerometer data. Figure 6.e is a detailed look at the three axes of TSH-A for the time period of figure 6.b from 164 to 184 seconds.

Acceleration Levels during BRS Operation

The data was examined for a 40 second time period starting at SET = 003:03:18:50 during the operation of the BRS rotating chair. Figure 7.a illustrates the acceleration levels of the three axes of TSH C which was mounted to the frame of the BRS chair. The corresponding spectrum plots in figure 7.b show a strong frequency component at 0.37 Hertz in the y-axis and z-axis which is apparently due to the chair operation. The strong peak at 4.7 Hertz in the x-axis is believed to be due to a Spacelab module or Orbiter structure resonance. The relatively large residual average levels of the TSH C acceleration data is being investigated to determine the source.

Acceleration Transfer From Center Aisle To SMIDEX Racks

Figures 8.a and 8.b illustrate the acceleration levels sensed by TSH's B & A, respectively, during the same time of BRS rotating chair operation as discussed in the previous subsection. Upon initial examination, it appears that a similar frequency content is present at each of the TSH locations. In particular, the 0.37 Hertz signal appears to be present at a comparable level as TSH C at the SSCE equipment.

FURTHER MISSIONS FOR SAMS

The second mission with a SAMS unit was the nine day STS-43 mission which was launched on August 2, 1991. The supported experiments were the SSCE, a Protein Crystal Growth experiment and the crew exercise treadmill. The sensor heads were set for 50, 50 and 2.5 Hertz. Nearly eight days of recorded data has been acquired for that mission which represents 2.76 gigabytes of data.

The third mission with a SAMS unit is planned to be STS-42, the first International Microgravity Laboratory, in early 1992. The supported experiments are the Fluid Experiment System (FES), the Vapor Crystal Growth System experiment. Two TSH's are installed in the FES rack and one is installed underfloor at the Microgravity Vestibular Investigation rotating chair. The sensor heads are set for 100, 100 and 2.5 Hertz. Six days of recorded data are expected for that mission which will represent approximately five gigabytes of data.

In addition to these missions, SAMS units are currently manifested on the remaining International Microgravity Laboratory missions, the United States Microgravity Laboratory series of missions, the United States Microgravity Payload series of missions, the SL-J mission, and, in general, two middeck missions per year. This will result in approximately four flights per year for the foreseeable future. On the majority of these missions, SAMS data is required to satisfy the science objectives of the experiments.

The planned flight activity for SAMS is shown in figure 9.

CONCLUDING REMARKS

The first flight of a SAMS unit appears to be an unqualified success with no anomalies during the initializations and operation. More definitive conclusions will be drawn as the vast quantity of data is analyzed further. The ACAP project will be analyzing this data and will be producing more detailed reports on the content of the data.

This Spacelab acceleration data will be of interest to Principal Investigators of SLS-1 and those who will have experiments on board the Orbiter in the future.

REFERENCES

[1] NASA Microgravity Strategic Plan -1990, NASA Headquarters Office of Space Science and Applications

[2] STS-40 Press Kit, Issued May 6, 1991, NASA Headquarters Newsroom

Table 1 SAMS Triaxial Sensor Head Orientation

SAMS Sensor Head Axis	Orbiter Axis Orientation (Approximate) (Orbiter Body Axis System)
TSH A (SSCE)	
X	- Y
Y	- X
Z	- Z
TSH B (Rack 5)	
X	Approximately 30 degrees from - Y toward + Z in the Y-Z plane.
Y	- X
Z	Approximately 60 degrees from - Y toward - Z in the Y-Z plane.
TSH C (BRS Frame)	
X	- Z
Y	+ X
Z	- Y

Table 2: Selected Significant Mission Events

MET (day:hr:min:sec)	EVENT
001:00:01:24	SAMS Power On (estimated)
001:00:59	SAMS Data Record On (note from POCC records)
001:01:01	SAMS Zero Calibration (approximate)
001:11:35	Thruster Firing (Orbiter yaw maneuver)
001:11:50 - 001:19:50	Crew Sleep Period (typical interval each mission day)
002:05:44	Ergometer Operation Start
002:20:50 - 002:20:55	Body Mass Measurement Operation
003:01:10 - 003:01:15	SSCE Operation
003:03:16 - 003:03:43	BRS Rotating Chair Operation
004:06:07	Ergometer Operation
004:09:55	Combined BRS & Ergometer Operation
004:19:30	First Disk Full (approximate)
005:00:19	SAMS TSH-C Cable Disconnected
005:00:40 - 005:04:40	Rotating Dome Experiment Operation (approximate)
005:04:49	SAMS Data Record Off and Power Off
005:04:50	SAMS TSH-C Cable Reconnected
005:04:52	SAMS Power On
005:04:54	SAMS Data Record On (approximate)
005:04:56	SAMS Zero Calibration
005:09:26	Crew Disk Change Operation Initiation
005:23:00 - 005:23:31	Orbiter Maneuvers for OARE
006:05:38	SAMS Data Record Off and Power Off
006:06:11	SAMS Power On (approximate)
006:06:13	SAMS Data Record On (approximate)
006:06:15	SAMS Zero Calibration (approximate)
008:01:40	SAMS Data Record Off (approximate)
008:02:00	SAMS Power Off (approximate)

Table 3 SAMS Acceleration Data Time Intervals

SET Time Interval (day:hr:min:sec)	Major Acceleration Activities
001:00:57:35 - 005:00:19:26	SSCE Operation BRS Chair Operation Zero Calibration Operation Four Crew Sleep Periods
005:00:19:26 - 005:04:49:00	TSH-A and TSH-B data only Zero Calibration Operation Rotating Dome Experiment
005:04:52:45 - 006:05:37:07	Orbiter Maneuvers for OARE One Crew Sleep Period
006:06:11:18 - 008:01:38:44	Two Crew Sleep Periods Zero Calibration Operation

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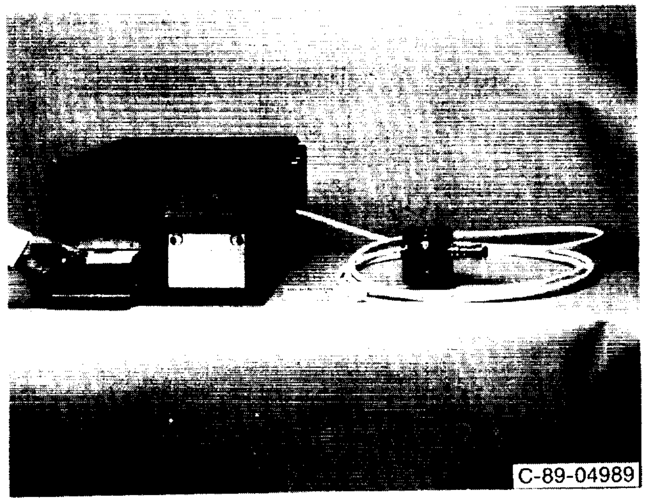


Figure 1.—SAMS main unit and triaxial sensor head.

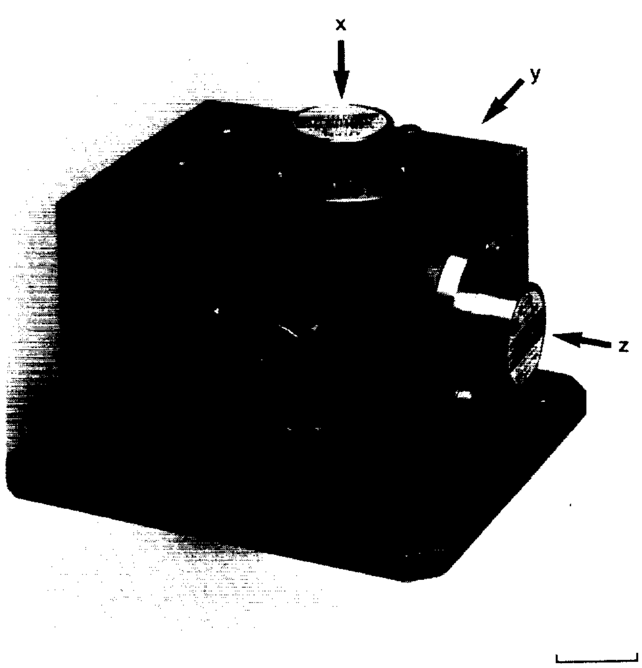


Figure 2.—SAMS triaxial sensor head axis definition.

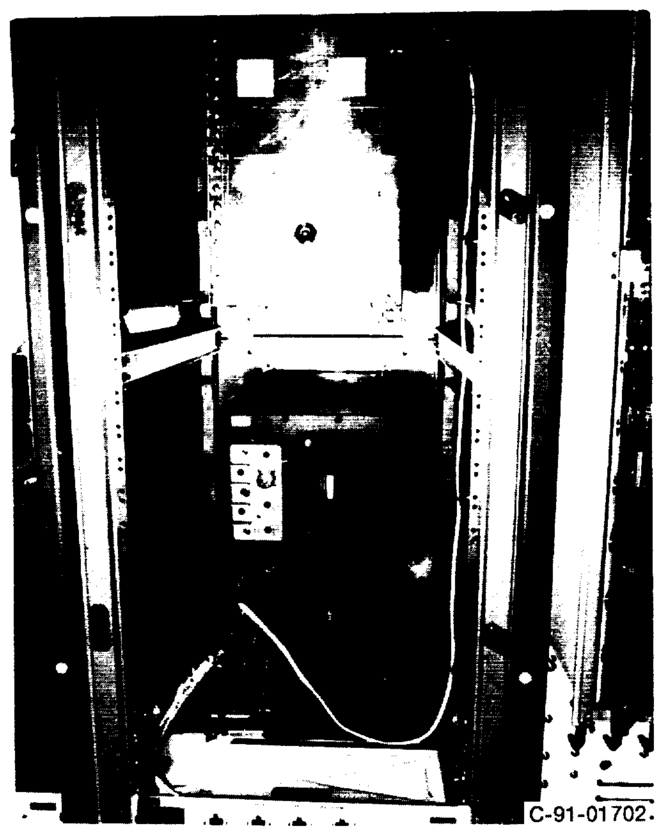
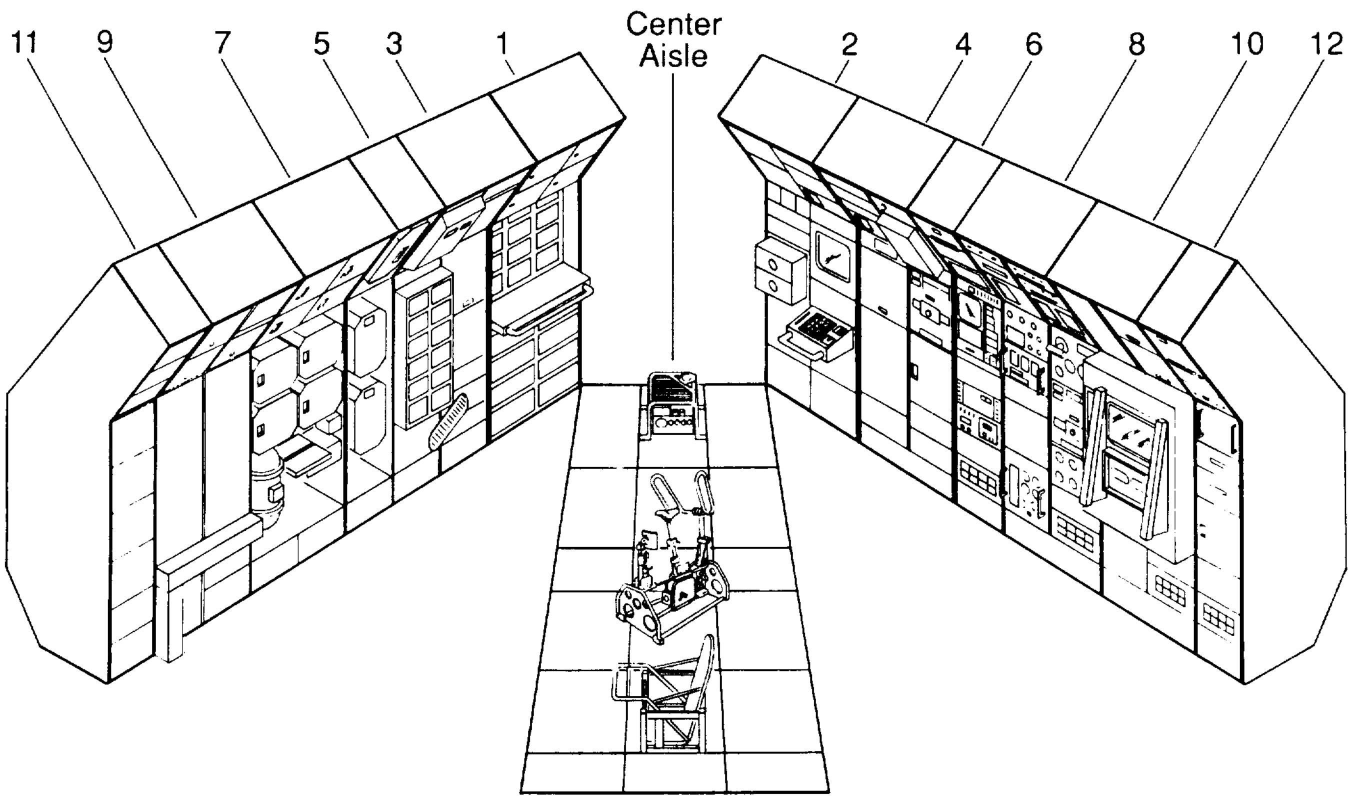


Figure 3.—Unit A installed in SMIDEX rack at KSC.



SLS-1 Spacelab Configuration

Port Racks

Rack 1: Workbench

Rack 3: Research Animal Holding Facility

Rack 5: SMIDEX single rack
Jellyfish experiment
Space Acceleration Measurement System

Rack 7: SMIDEX double rack
Solid Surface Combustion Experiment
Noninvasive Central Venous Pressure
Intravenous Infusion Pump
American Flight Echocardiograph
Surgical Work Station

Rack 9: Refrigerator/Freezer
Small Mass Measurement Instrument

Rack 11: Baroreflex Neck Pressure Chamber and electronics
Rotating Dome
Incubator
Low-g Centrifuge

Center Aisle

Body Restraint System

Bicycle Ergometer

Body Mass Measurement Device

Starboard Racks

Rack 2: Control Center

Rack 4: Television and video monitoring equipment
Spacelab support services
Gas Analyzer Mass Spectrometer

Rack 6: Echocardiograph
Experiment Command and Data System/Microcomputer System

Rack 8: Gas Analyzer Mass Spectrometer
Rebreathing Assembly Unit
Life Sciences Laboratory Equipment (LSLE) Microcomputers
Vacuum Interface Assembly
Video Monitor
Cardiovascular/Cardiopulmonary Interface Panel
Cardiopulmonary Control Unit
Gas Tank Assembly

Rack 10: General Purpose Work Station

Rack 12: LSLE Centrifuge

Figure 4.—SLS-1 module interior locations.

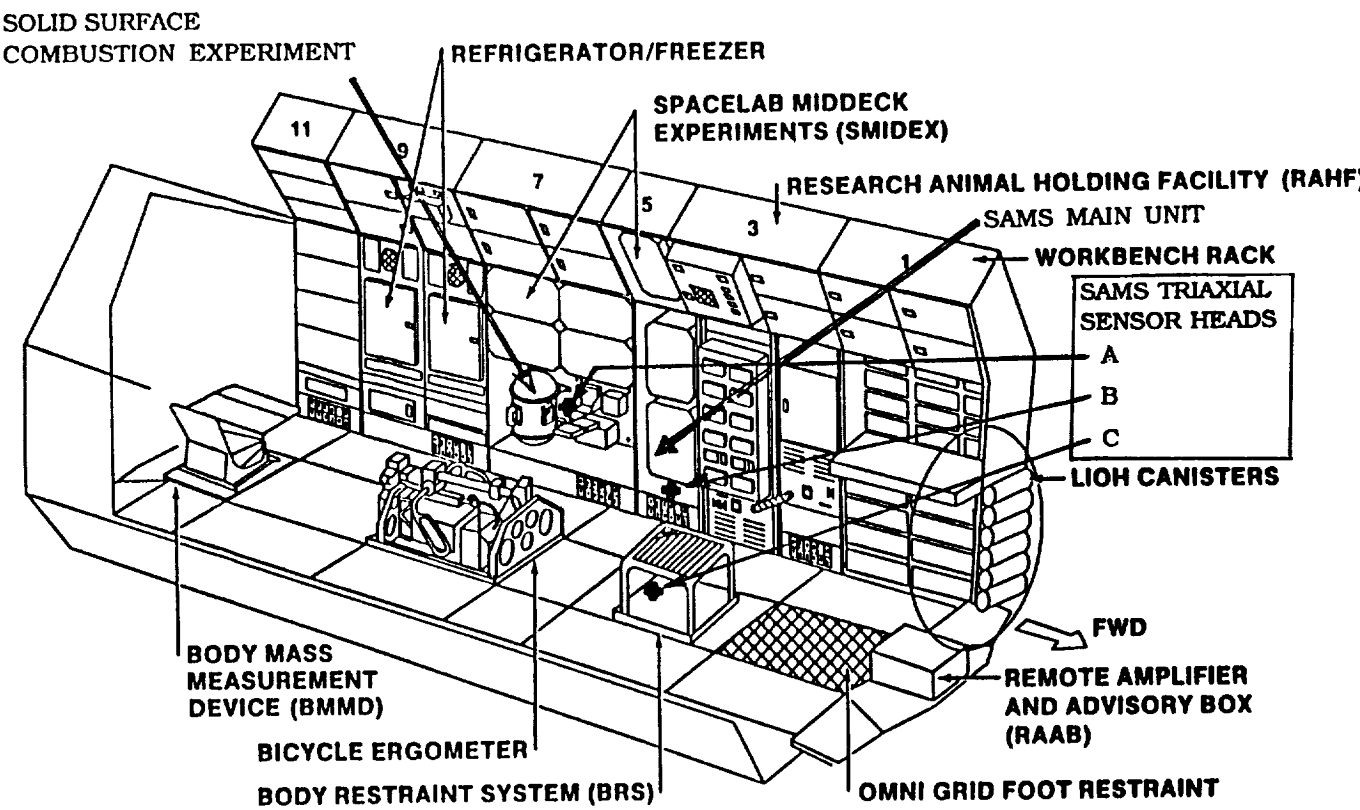
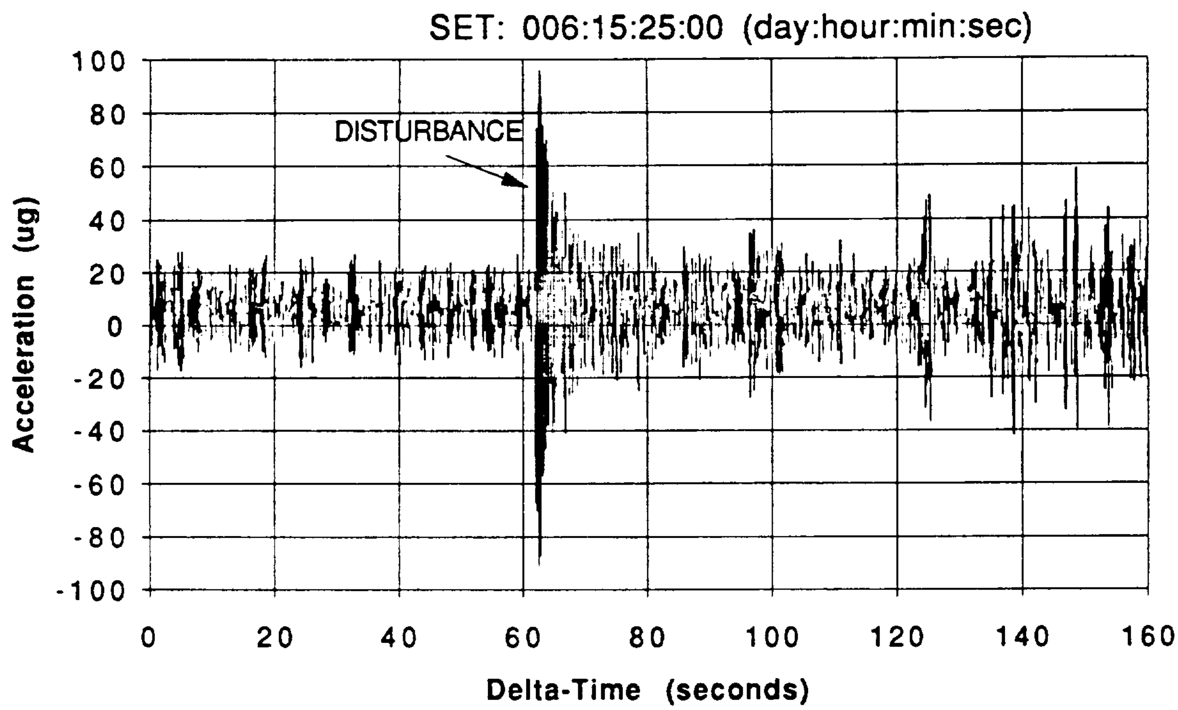
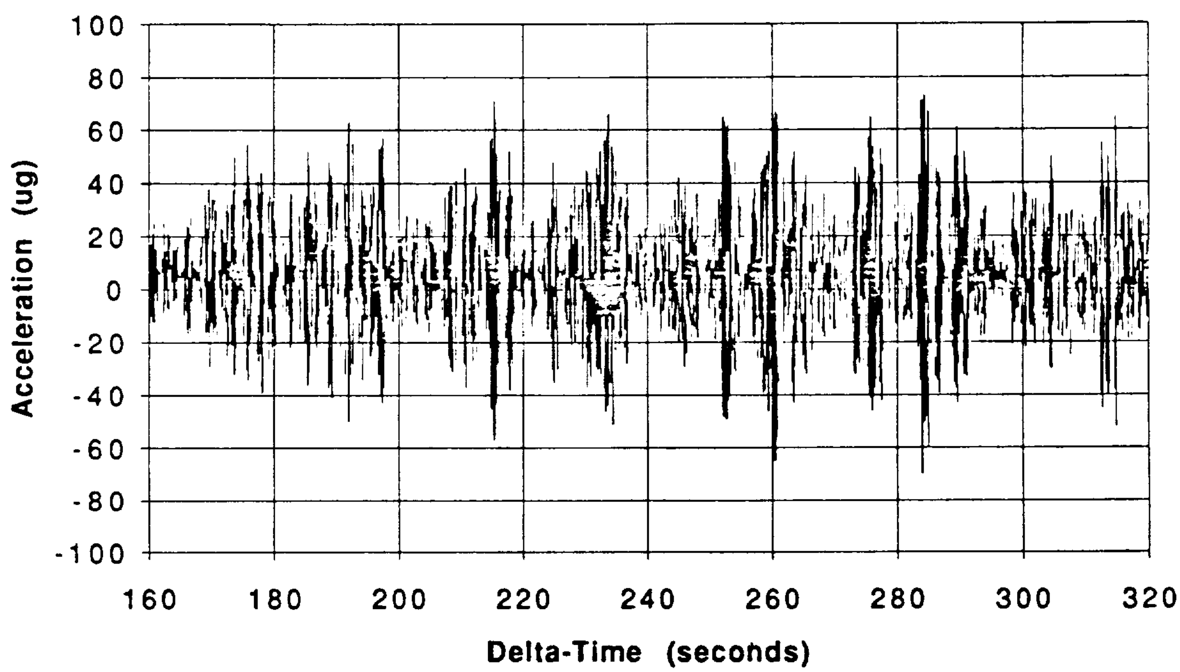


Figure 5.—SAMS triaxial sensor head locations.

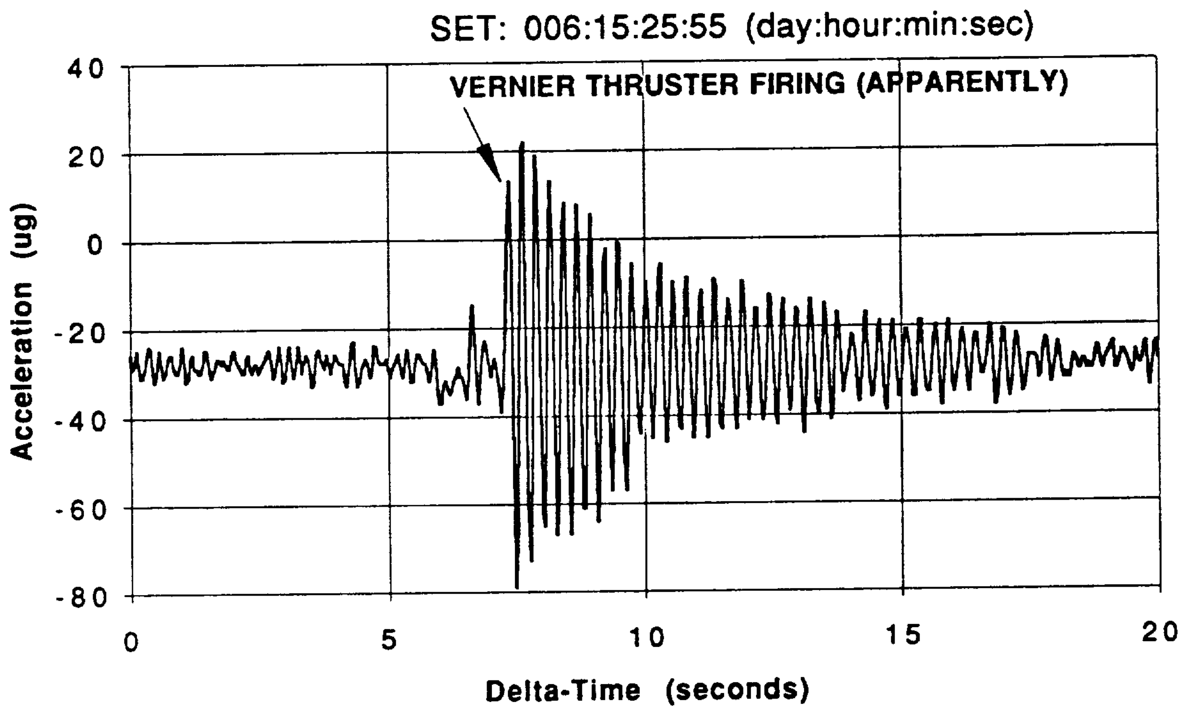


(a) Acceleration versus time (TSH-A, x-axis).

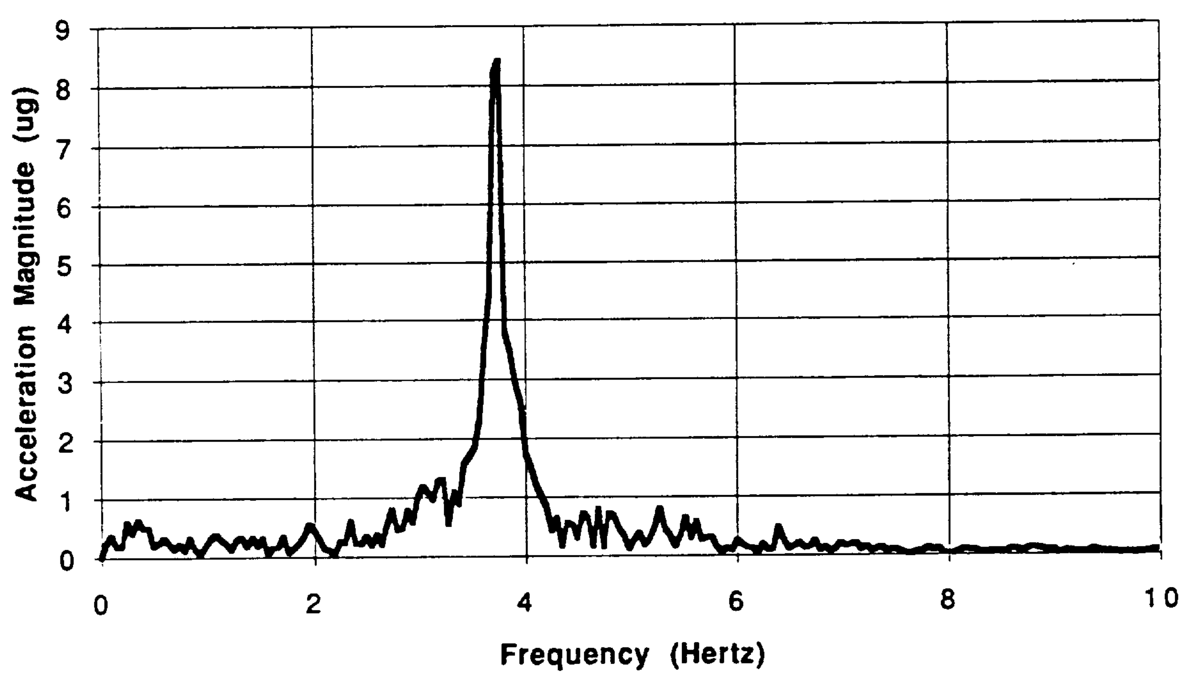


(b) Acceleration versus time (TSH-A, x-axis).

Figure 6.—Acceleration levels during quiet crew activity.

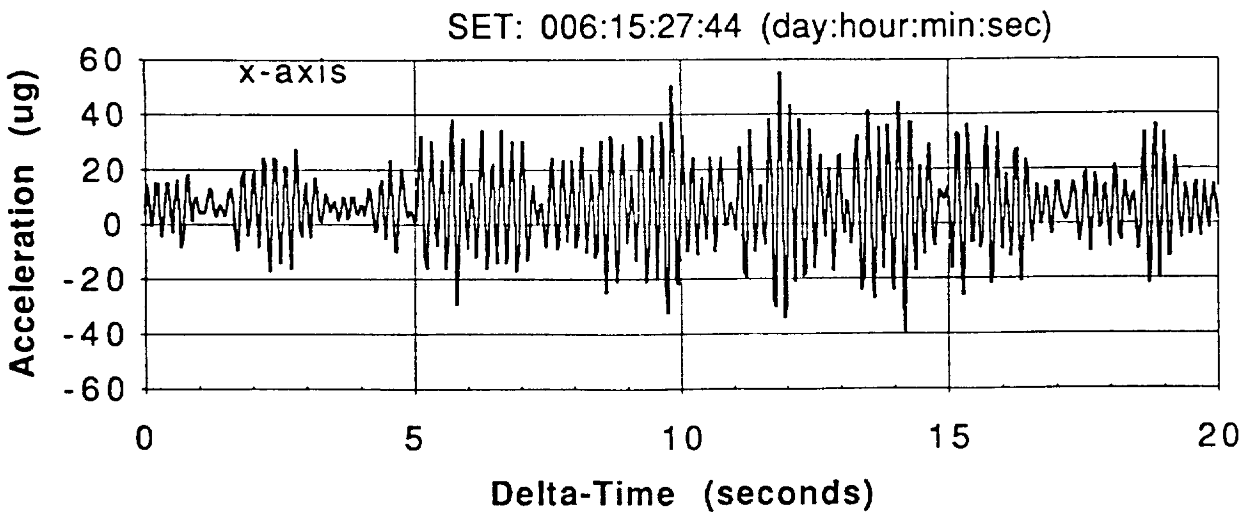


(c) Acceleration versus time (TSH-A, y-axis).

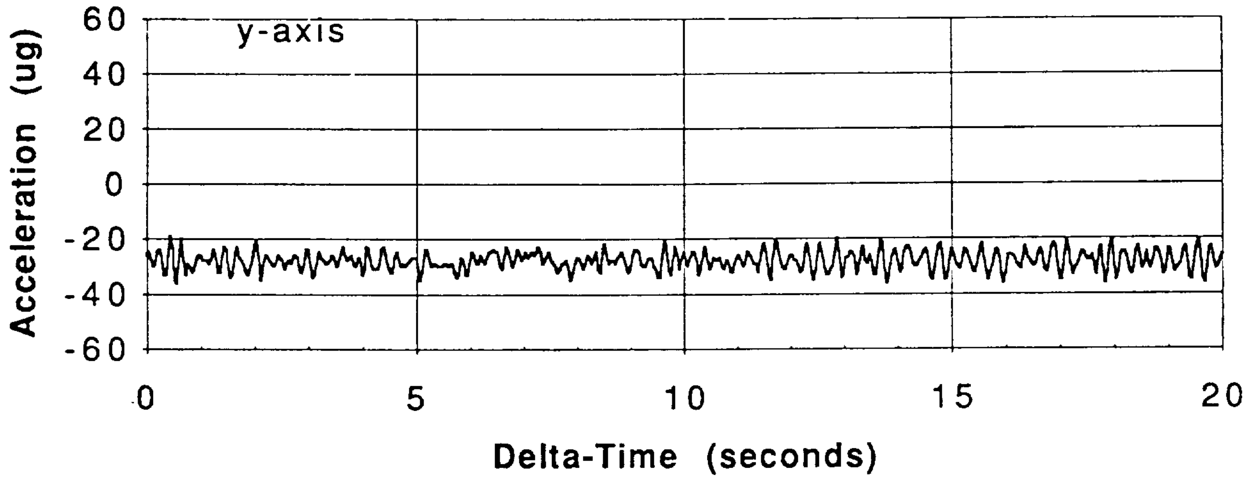


(d) Acceleration versus frequency (TSH-A, y- axis).

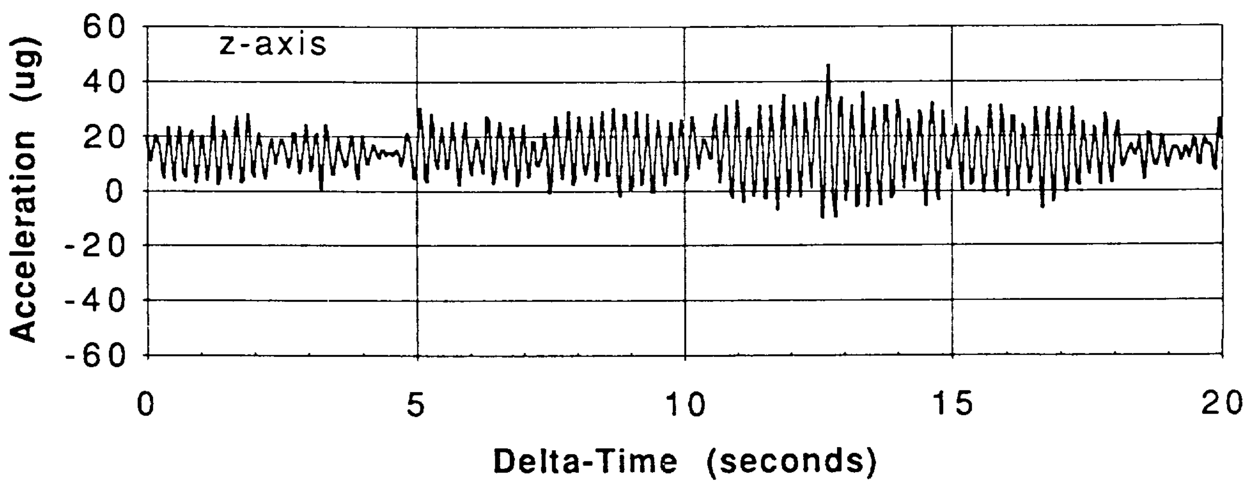
Figure 6.—Continued.



TSH-A, x-axis



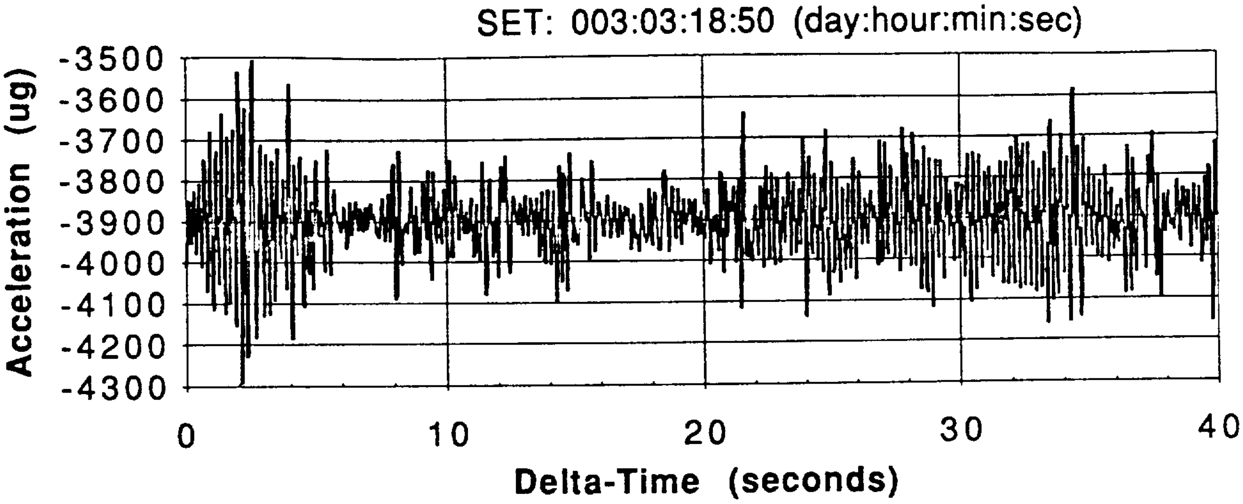
TSH-A, y-axis



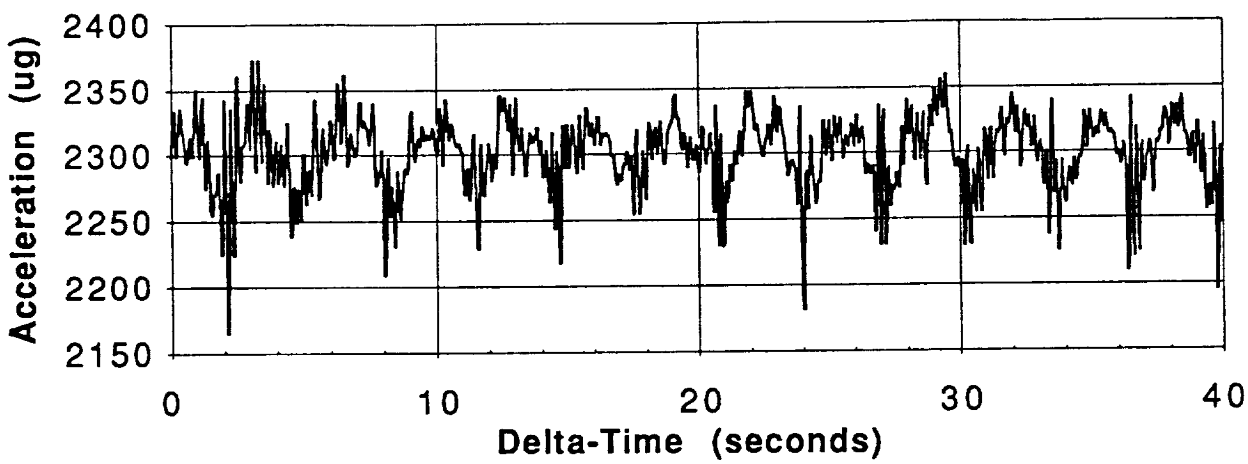
TSH-A, z-axis

(e) Acceleration versus frequency (TSH-A, x, y, z axes).

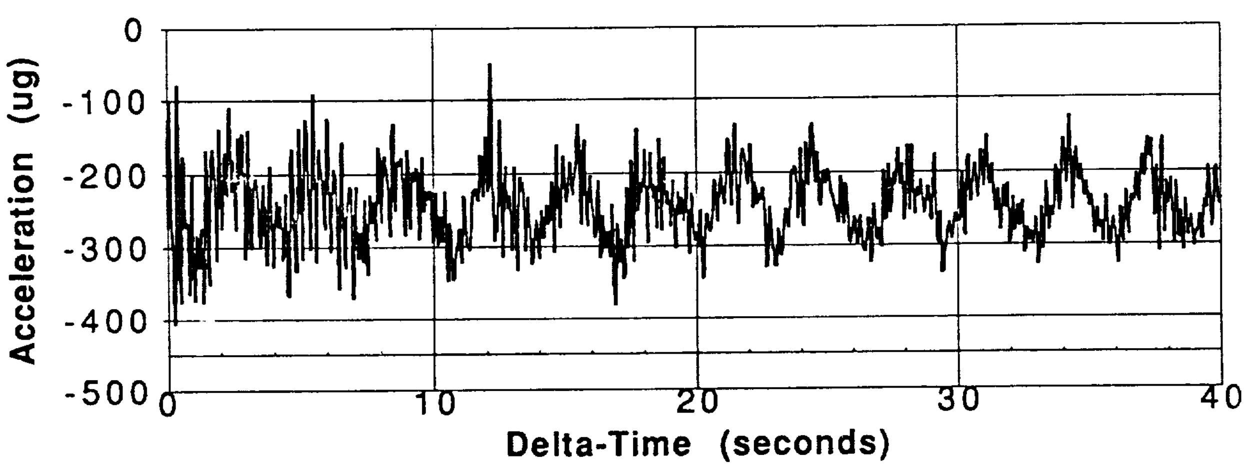
Figure 6.—Concluded.



TSH-C, x-axis



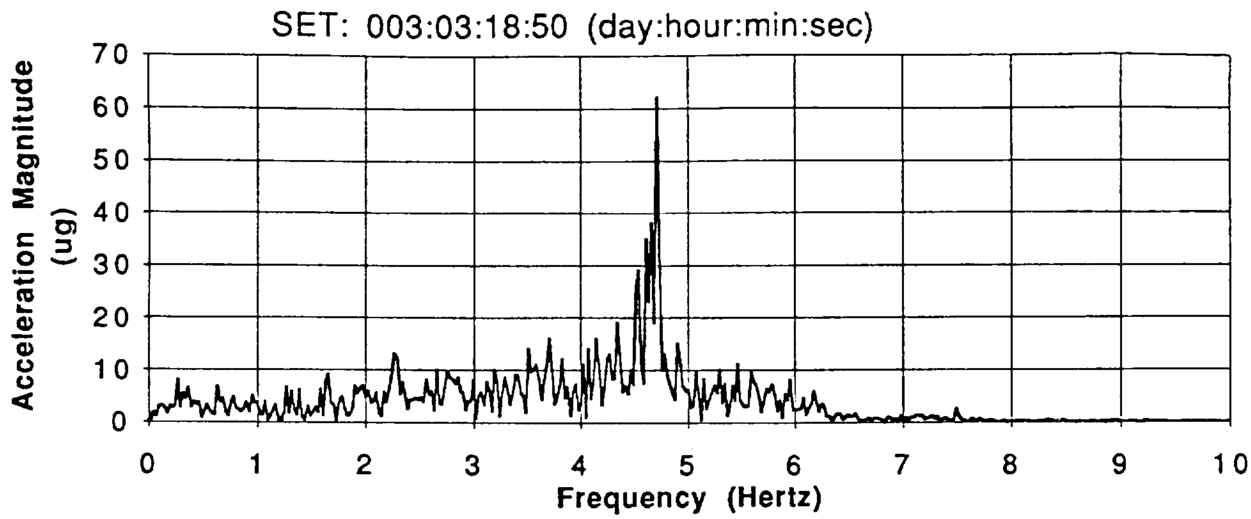
TSH-C, y-axis



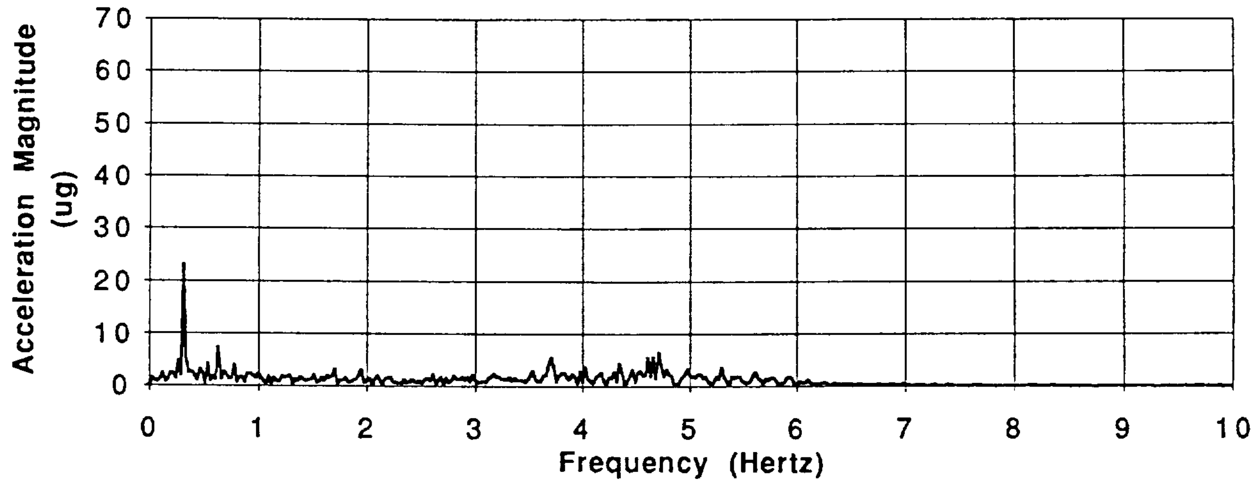
TSH-C, z-axis

(a) Acceleration versus time.

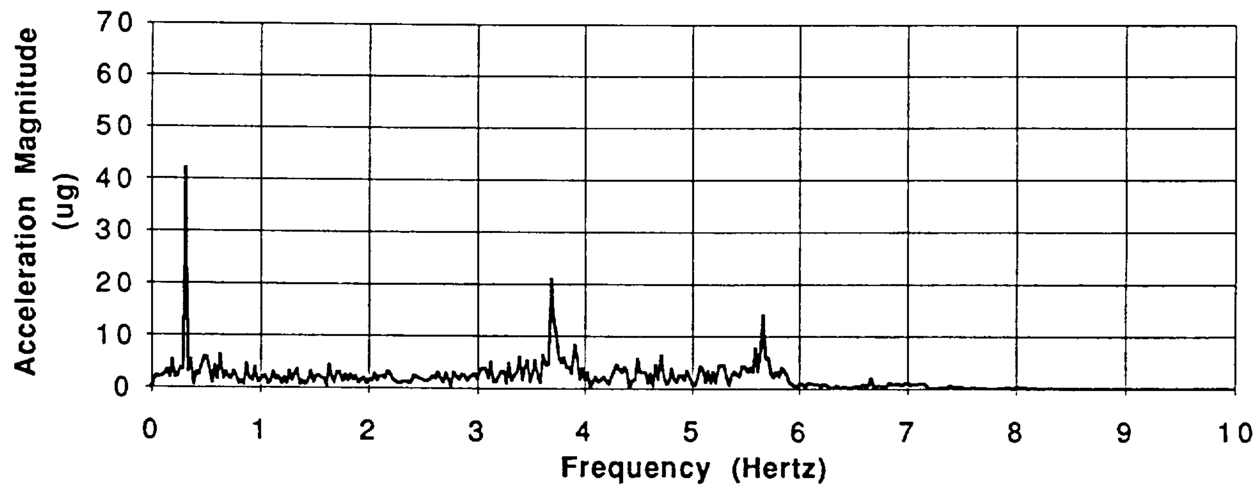
Figure 7.—Acceleration levels during BRS operation.



TSH-C, x-axis



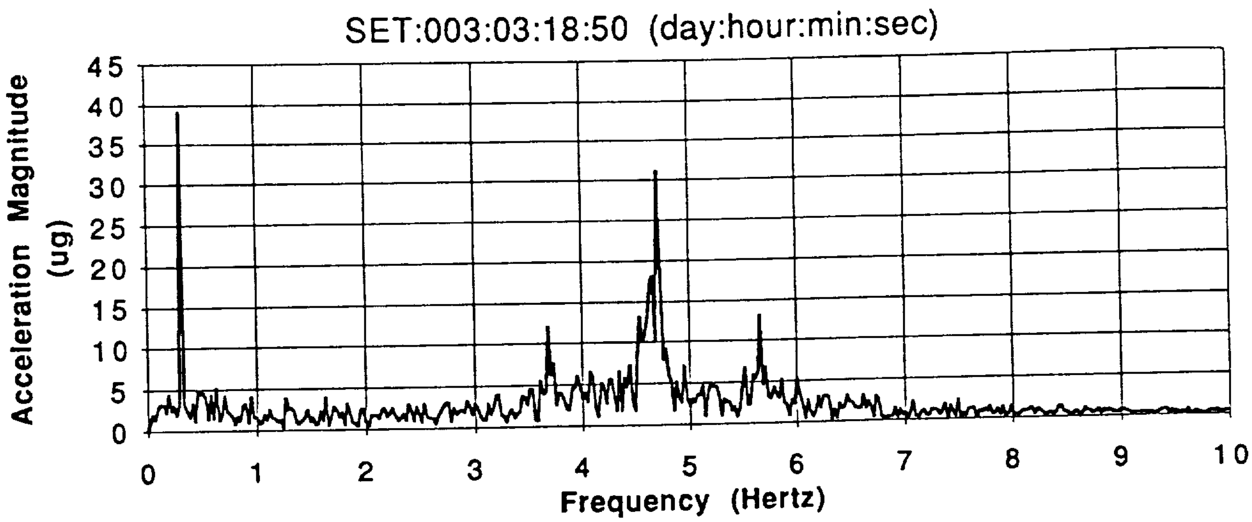
TSH-C, y-axis



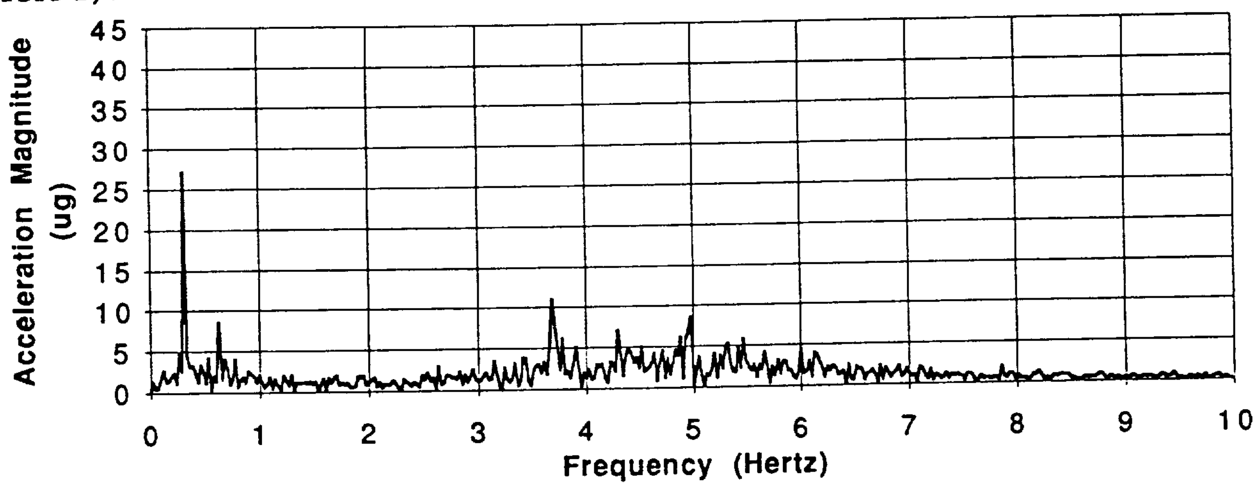
TSH-C, z-axis

(b) Acceleration versus frequency.

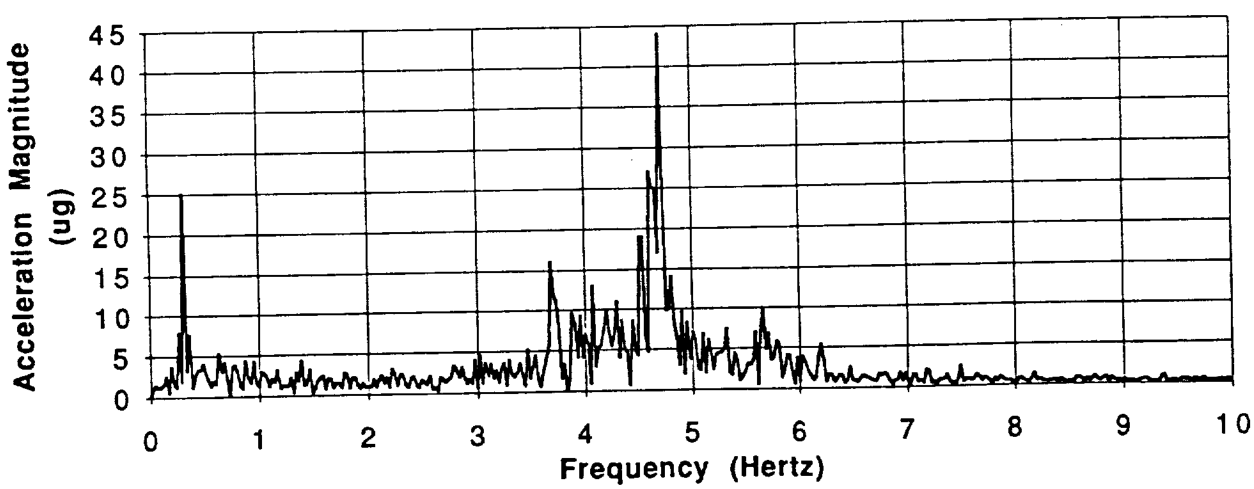
Figure 7.—Concluded.



TSH-B, x-axis



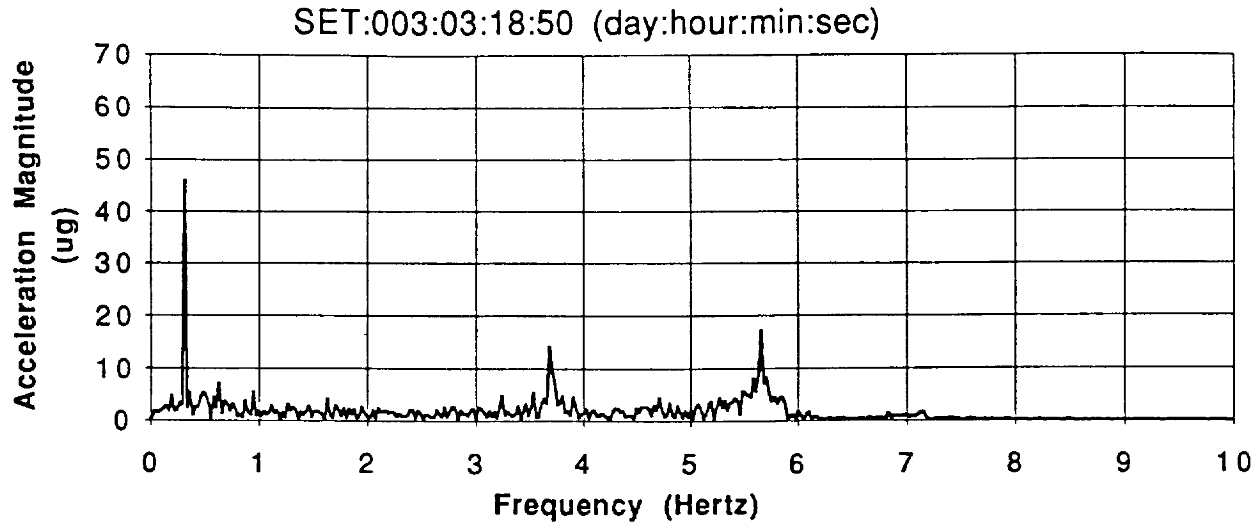
TSH-B, y-axis



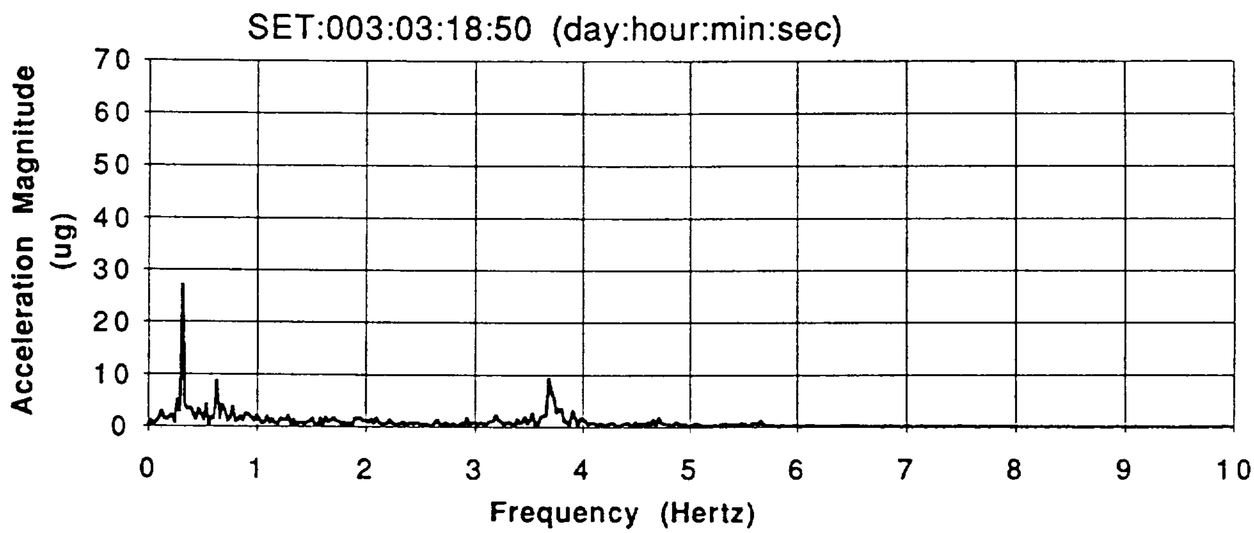
TSH-B, z-axis

(a) Acceleration versus frequency.

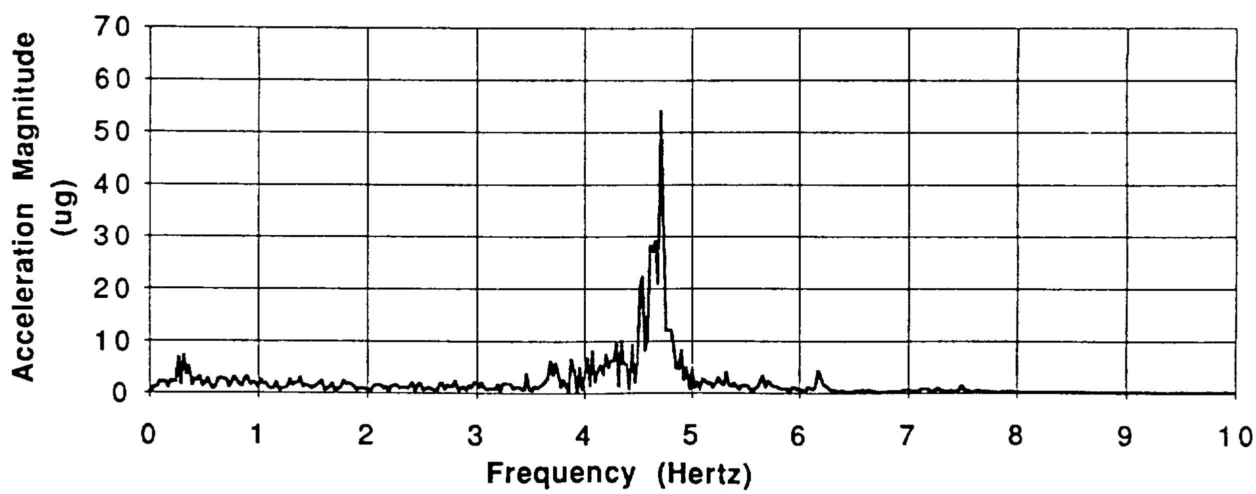
Figure 8.—Acceleration levels during BRS operation.



TSH-A, x-axis



TSH-A, y-axis



TSH-A, z-axis

(b) Acceleration versus frequency.

Figure 8.—Concluded.

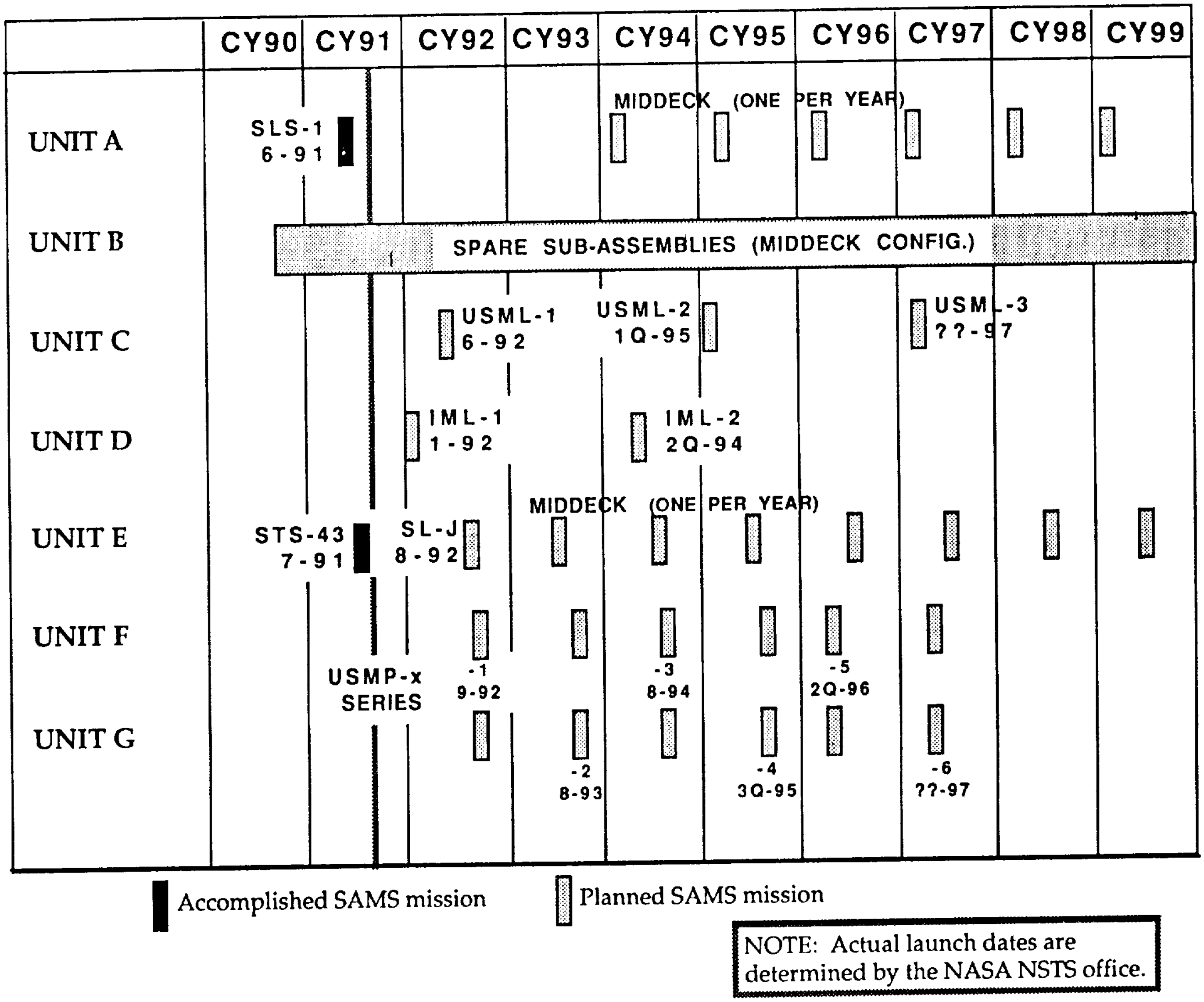


Figure 9.—SAMS flight planning schedule.

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13. ABSTRACT ***(Maximum 200 words)***

This report briefly describes the Space Acceleration Measurement System (SAMS) project and flight units, summarizes the SAMS operations during the STS-40 mission, and provides a preliminary look at some of the acceleration data from that mission. The background and rationale for the SAMS project is described to better illustrate its goals. The functions and capabilities of each SAMS flight unit are first explained, then the STS-40 mission, the SAMS unit's functions for that mission, and the preparation of the SAMS unit are described. Observations about the SAMS operations during the first SAMS mission are then discussed. Some sample data are presented illustrating several aspects of the mission's microgravity environment.

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